

# THE INTEGRAL/IBIS TELESCOPE MODELING

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## ABSTRACT

The main objective of the IBIS modeling activities is the generation of the IBIS spectral response matrix. This generation will be done step by step by firstly constructing “calibrated model” of each IBIS sub-systems. A “calibrated model” is defined as a GEANT Monte-Carlo model, further checked by intensive corresponding calibration. These calibrated models will be in a second step integrated in the whole IBIS Mass Model. This Mass Model will be checked and refined using the data obtained during the IBIS Telescope calibration, the PLGC during the ETET period, and the In-flight calibration data acquired during the whole INTEGRAL mission. The IBIS Mass Model will be used also for computations of efficiencies and transparencies. Some imaging studies (such as the study of the diffuse emission) may be also done with the help of the IBIS Mass Model. The IBIS Mass Model may be used for the simulation of IBIS data in order to check the different IBIS software.

Key words: IBIS; Modeling; Response Matrices.

## 1. THE INTEGRAL SATELLITE AND ITS INSTRUMENTS

INTEGRAL is a 15 keV-10 MeV  $\gamma$ -ray mission with concurrent source monitoring at X-rays (3-35 keV) and in the optical range (V, 500- 600 nm). All instruments are coaligned and have a large FOV, covering simultaneously a very broad range of sources. The INTEGRAL payload consists of two main  $\gamma$ -ray instruments, the spectrometer SPI and the imager IBIS, and of two monitor instruments, the X-ray monitor JEM-X and the Optical Monitoring Camera OMC.

The Imager on Board Integral Satellite (IBIS) provides diagnostic capabilities of fine imaging (12' FWHM), source identification and spectral sensitivity to both continuum and broad lines over a broad (15 keV–10 MeV) energy range. It has a continuum sensitivity of  $2 \cdot 10^{-7}$  ph cm<sup>-2</sup> s<sup>-1</sup> at 1 MeV for a 10<sup>6</sup> seconds observation and a spectral resolution better than 7 % @ 100 keV and of 6 % @ 1 MeV. The imaging capabilities of the IBIS are characterized by the coupling of its source discrimination capability (angular resolution 12' FWHM) with a field of view (FOV) of 9° × 9° fully coded, 29° × 29° partially coded FOV.

The spectrometer SPI will perform spectral analysis of  $\gamma$  ray point sources and extended regions with an unprecedented energy resolution of  $\sim 2$  keV (FWHM) at 1.3 MeV. Its large field of view (16° circular) and limited angular resolution (2° FWHM) are best suited for diffuse sources imaging but it retains nonetheless the capability of imaging point sources. It has a continuum sensitivity of  $7 \times 10^{-8}$  ph cm<sup>-2</sup> s<sup>-1</sup> at 1 MeV and a line sensitivity of  $5 \times 10^{-6}$  ph cm<sup>-2</sup> s<sup>-1</sup> at 1 MeV, both  $3\sigma$  for a 10<sup>6</sup> seconds observation.

The Joint European Monitor JEM-X supplements the main INTEGRAL instruments and provides images with 3' angular resolution in a 4.8° fully coded FOV in the 3-35 keV energy band. The Optical Monitoring Camera (OMC) will observe the prime targets of INTEGRAL main  $\gamma$  ray instruments. Its limiting magnitude is  $M_V \sim 19.7$  ( $3\sigma$ , 10<sup>3</sup> s). The wide band observing opportunity offered by INTEGRAL provide for the first time the opportunity of simultaneous observing over 7 orders of magnitude.

## 2. IBIS MODELING

The generation of the IBIS response matrices will be done step by step by firstly constructing “cali-

brated model” of each IBIS sub-systems. A “calibrated model” is defined as a GEANT Monte-Carlo model (Brun et al. 1994), further checked by intensive corresponding calibration. These calibrated models will be in a second step integrated in the whole IBIS Mass Model. This Mass Model will be checked and refined using the data obtained during the IBIS Telescope calibration, the PLGC during the ETET period (Carli et al., 2000), and the In-flight calibration data acquired during the whole INTEGRAL mission. We will detail below the status of this activity.

### 2.1. IBIS QM modeling

In a first step, we have made a model of the IBIS QM by assembling the GEANT calibrated models of all the different IBIS sub-systems constituting the QM. This model has been used to plan the QM calibration, and will be checked against the results of these calibration which have occurred on September 2000. Figure 1 shows a cut-view of this QM model in the X-Z plane. We could see ISGRI in green, PiCsIT in black, and the Veto module in red. In blue is the IBIS Detector Unit (DU) structure. We could see in figure 2 a drawing of the model where the ISGRI QM module is shown in red.

### 2.2. IBIS DU and FM Modelling

In a second step, every IBIS sub-system will create a calibrated FM model of its system. The ISGRI, PiCsIT, Veto, and frame will be then “integrated” to form the virtual Detector Assembly system, which will be checked against the calibration to be made in December 2000. Then, we will add to the Detector Assembly model all the other IBIS sub-systems in order to create the model of the full IBIS FM telescope, and the results of the simulations will be compared to the IBIS FM calibration (March-April 2001). Figure 3 shows the result of a run made with our “uncalibrated” IBIS full model. It is an ISGRI image resulting from this simulation, where the source were at the center of the IBIS field of view.

### 2.3. Response Matrix generation

A simplified model of the response matrix will be available for testing interfaces with the ISDC system at Fall 2000. The first IBIS FM calibrated Mass Model should be available sometimes after the IBIS FM calibration, that is at mid 2001. This will enable the generation of the first issue of the response matrix, which will be checked and refined using the results obtained during the Payload Ground Calibration done during the ETET period (mid 2001, Carli et al., 2000). A response matrix could be generated for each IBIS type of data : ISGRI, PiCsIT single, PiCsIT multiple, Compton single, Compton

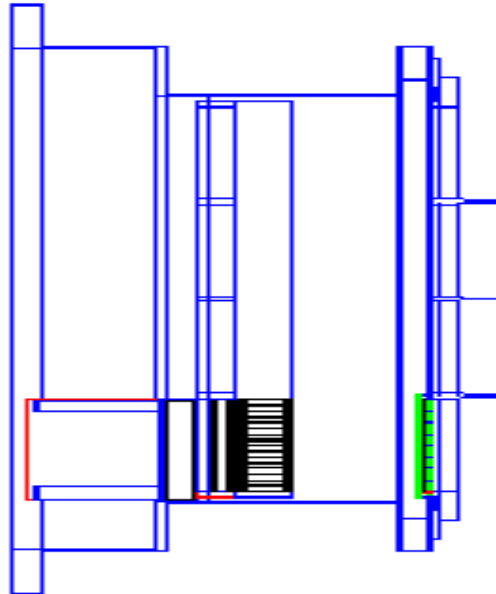


Figure 1. Side view of the QM GEANT Model .

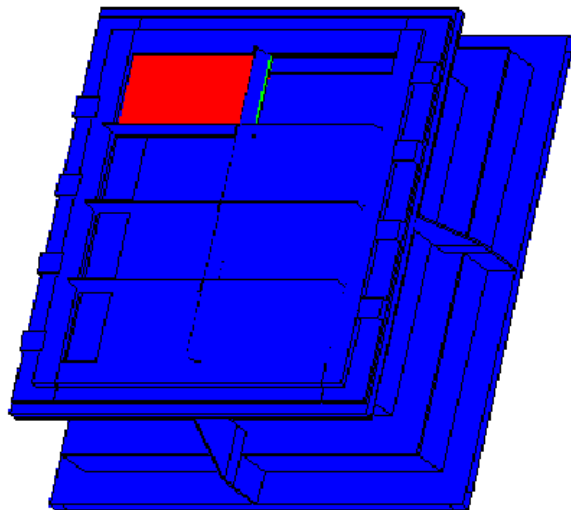


Figure 2. Top view of the QM GEANT model.

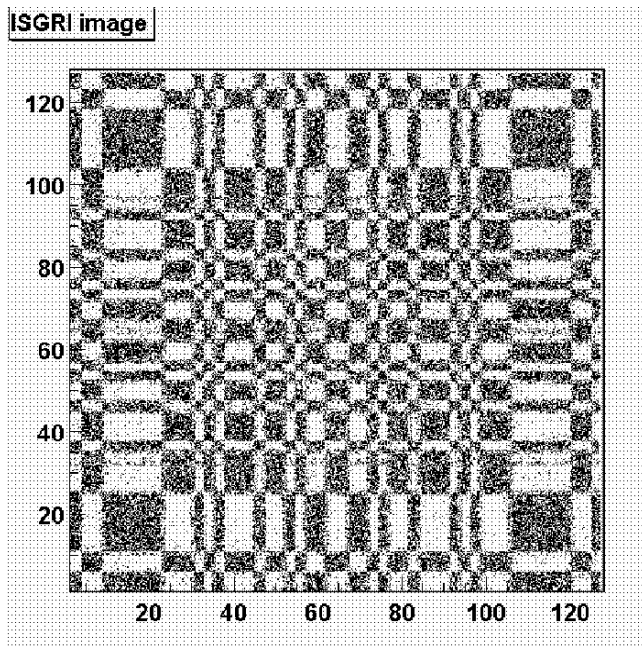


Figure 3. Simulated ISGRI Image.

multiple, and Spectral Timing. These matrices will be constructed from the simulated IBIS response to an on-axis source. The shadowing effects for an off-axis source will be taken into account during the image deconvolution process, using transparency maps derived for a given off-axis source direction. These maps will be checked for some directions using the results from the full IBIS FM calibration and the Payload Ground Calibration.

#### 2.4. link with the XSPEC package

As seen in Figure 4, the results of the IBIS modeling may be transformed in XSPEC compatible formats, and used within this package. In the figure, we have also taken into account the following estimates for the IBIS background values:

ISGRI mode : 1000 cts/s  
 PiCsIT mode : 7500 cts/s  
 Compton mode : 100 cts/s

in order to compute the error bars. We have then fit these spectra with XSPEC, giving the model spectrum shown in Figure 4. This fitted spectrum is composed by a power law with photon index  $\alpha = -2.4$  and a line centered at an energy of 480 keV with a 22 keV width, parameters which are consistent with the parameters we introduced as input in our Monte-Carlo simulations.

#### REFERENCES

- Brun R. et al. 1994, CERN Program Library Long Wwriteup W5013, 1994  
 Carli R. et al., 2000, this conference

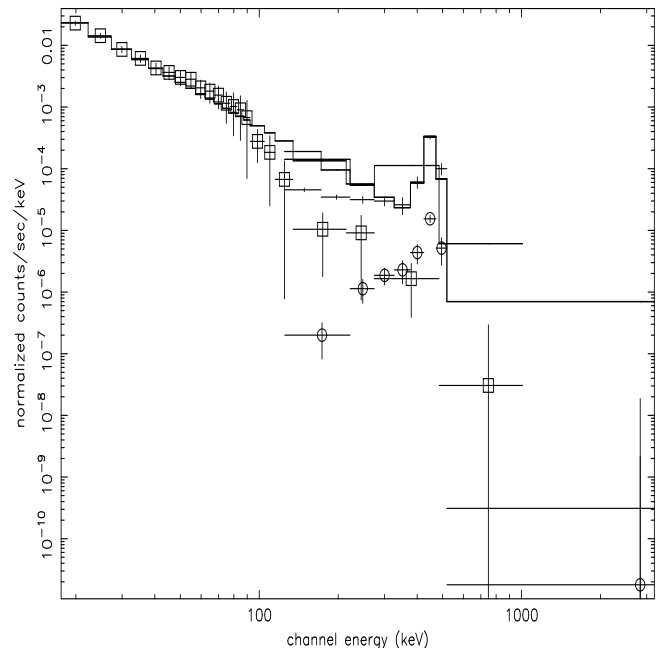


Figure 4. Simulated IBIS raw spectra as introduced in XSPEC, shown with a powerlaw + 511 keV line fit. ISGRI points are indicated by squares, PiCsIT points by crosses and Compton points by stars. The fitted model spectrum composed by a power law with photon index -2.4 and a line centered at an energy of 480 keV with a 22 keV width is also shown.